June 17, 2002
Volume 80, Number 24
CENEAR 80 24 p. 4
ISSN 0009-2347

MOLECULAR ELECTRONICS

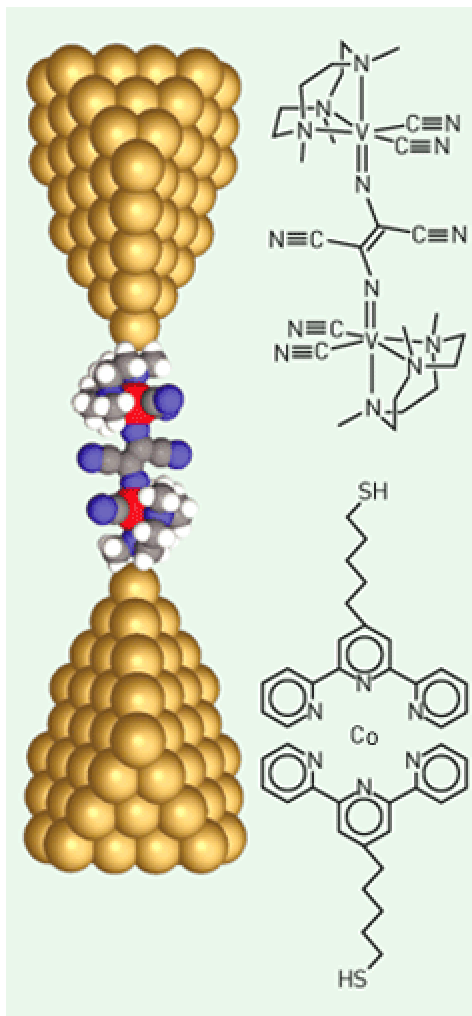
METAL ATOMS TAKE CHARGE

Single molecules of metal complexes govern nanoelectronic properties

MITCH JACOBY

Making electronic devices in which performance is controlled by a single molecule seemed like a far-fetched idea just a few years ago. But since then, scientists have created circuits and simple devices based on a single carbon nanotube, a C_{60} molecule, and other molecules.

Now, two research groups independently report taking another key step toward creating tomorrow's molecular electronic devices. The scientists fabricated and tested transistors in which one molecule of a transition-metal organic complex bridges the nanometer-scale gap between the devices' electrodes and dictates their electronic properties [*Nature,* **417,** 722 and 725 (2002)].



IN THE GAP
Single-molecule electronic devices are based upon the properties of a

In one of the studies, Harvard University chemists Hongkun Park and Wenjie Liang; Jeffrey R. Long of the University of California, Berkeley; and coworkers prepared a triazacycloalkyl complex containing two vanadium atoms and trapped the molecule between the electrodes of a microscopic transistor.

In the other investigation, which was conducted at Cornell University, physicists Paul L. McEuen, Daniel C. Ralph, Jiwoong Park, and Abhay N. Pasupathy; chemist Héctor

D. Abruña; and coworkers compared the electronic properties of two coordination complexes in which a cobalt ion, whose charge state is readily switched between 2+ and 3+, is bonded to two terpyridinyl molecules with thiol end groups. The pair of molecules differ by a five-carbon alkyl chain that serves as a spacer between the terpyridinyl units and the end groups.

lone molecule trapped in a nanosized gap between electrodes. A Harvard-Berkeley team prepared devices based on a complex with two vanadium atoms (top), while a Cornell team studied cobalt-terpyridinyl complexes (bottom).

Because there is no simple method for directly imaging a lone molecule sitting between a pair of electrodes, both research groups measured electrical conductance properties of their specimens and showed that the devices exhibit single-molecule signatures. The teams also showed that the nanostructures indeed behave as transistors in that the flow of electrical current can be turned on or off by controlling the voltage on an electrode known as a gate.

The Cornell group found that the alkyl-chain spacers included in one of their molecules weaken the molecule's electronic coupling to the electrodes. The molecule with the spacer conducts via a single-electron tunneling mechanism. By contrast, in the other molecule, conductance involves a Kondo resonance—a strong correlation between the spin on the cobalt ion and the spins of the electrons in the electrodes. Similarly, the Harvard team observed a Kondo resonance and found that the effect could be controlled by using the gate voltage to tune the charge and spin state of the vanadium complex.

"This work shows that we can use chemical synthesis to make molecules with specific properties that are reflected in the electronic behavior of a single-molecule transistor," McEuen says. "This means that we can learn about the physics of molecules from electronic measurements and design new kinds of single-molecule devices using chemistry."

Harvard's Park remarks that "by studying these systems and the way they conduct current, we can learn a great deal about the way electrons flow through molecules. Such studies lay the foundation of possible future technologies such as molecular electronics and quantum computing."

Do the latest reports of single-molecule transistors mean molecular electronic devices will be on store shelves by next holiday season? Certainly not. Writing in the same issue of *Nature*, Leo Kouwenhoven and Silvano De Franceschi of Delft University of Technology, in the Netherlands, note that "the goal may be a little closer but there is still a long road ahead before atomic or molecular devices can be assembled into viable, dense, fast logic circuits." The work represents scientific and technological progress, they say, but for now, the new devices "are no competition for silicon transistors."

Top
